REMARKS:

The official action has been carefully considered and the Examiner's comments are duly noted. Reconsideration of this application in light of the amendments for the claims and the remarks submitted is respectfully solicited.

While no extension is considered to be necessary, please use this as your authorization to obtain any extensions, which are necessary, and charge the cost to our Deposit Account # 10-0100.

For the sake of the record, the claims have been rewritten because of the extensive amendments, and applicant's Attorney wants to be certain that the claims that the Examiner considers are the appropriate claims in view of the fact that the claims during the PCT Examination were changed.

Turning now more specifically to the detailed action and the claims objections in paragraph 1, with respect to claims 11-14 and 17, which were objected under 37 CFR 1.75(c), these claims have been rewritten, and it is now believed that they are free from such objection and are in good form. If there is any point outstanding in this connection, the Examiner is respectfully asked to call applicant's Attorney in or order to do what is necessary.

Turning now more specifically to the claims rejection under 35 USC Paragraph 102, it is noted for the sake of the record, that claims 1-10 were rejected under 35 USC 102(b) as being anticipated by Rinderle, U.S. Patent No. 4,387,762.

The Examiner's comments concerning Rinderle have been fully considered, but a consideration of Rinderle by the applicant clearly gives the applicant the impression that a different interpretation can be made of Rinderle. It is respectfully submitted as

will be pointed out hereinafter, that the subject matter of the invention, as now claimed in all of the claims, clearly distinguishes from Rinderle alone and Rinderle combined with any of the other references of record, which will be discussed subsequently.

For the sake of the record, and the applicant's desire to bring to the Examiner's attention, the invention is specifically applicable to moulds used for plastic injection and the invention solves a number of very difficult problems that have hitherto plagued this particular area. This will be discussed separately in connection with Ex Parte MASHAM 2 USPQ 2d-1647. New claim 26, which is based on former claim 9, is specifically directed as an independent claim to this feature. New claim 23 based on former claim 6 is also directed to this feature claim 27 based on claim 10 also directed to this feature.

The technique particularly allows for effective heat transmission through the die so that the total overall temperature of the die is kept relatively uniform and heat can be gotten rid of by having external cooling water somewhere in the top of the die where it can act in a very efficient way by acting to condense the water vapor.

However, apart from a relatively small area of the die, the traditional techniques of using cooling water that continuously flows through pretty much all of the die is no longer needed.

As the Examiner will now readily appreciate this then provides firstly for significantly reduced cycle times through an injection moulding process and further, because external water is not being introduced other than through a very small portion of the mould, the life of the die can be expected to be very much longer.

There is quite simply nothing that the inventor knows of that solves these particular problems in this way.

Now referring to the prior art, Rinderle does understand the problem that the applicant wants to solve and describes this quite well, but Rinderle has an answer, which is different from the current applicant.

As it will be explained hereinafter, the Examiner will readily appreciate that both applicant and Rinderle were considering the same problem, but the applicant's solution, at least in the applicant's opinion, is much better as clearly evident from the description in the specification of this application.

The Examiner's attention is directed to column 3, lines 43 of Rinderle and onward, which states: "The cooling of at least one portion of the mould cavity surface is controlled independently of the cooling of other portion(s) of the mould cavity surface. The cooling control means preferably has a sufficiently fast response time, such that the moulding cycle is not significantly extended. The cooling control means preferably comprises variable conductance heat pipes and most preferably volume controlled variable conductance heat pipes having means for controlling the liquid volume and/or total fluid content within the heat pipe(s)."

In contradiction, the current applicant does not use heat pipes, which are a separate device, but in fact uses a chamber within the mould.

Further, however, Rinderle specifically discloses a heat tube with means to vary the volume of the chamber to achieve a variable conductance of heat effect. In applicant's claimed invention, there is no variation of the size of the mould.

The discovery of the current applicant and his contribution is that by, in a sense, having the chambers integrated within the mould itself and then using partial pressure techniques, one can then have a mould that provides these tremendous additional

advantages which one would never get in a million years by trying to locate lots and lots of heat pipes all over the place.

Claim 1 was rewritten as new claim 18 and now sets forth that -- the liquid having a volume such that it has an upper level above one of the areas of the mould to be cooled and substantially only the vapor of the liquid within the chamber, above the upper level of the liquid and further that the total overall temperature of the mould is kept relatively uniform and provides for effective heat transmission through the mould --.

All of the claims in this application have either been amended directly or indirectly. Where the claims have been amended indirectly, these claims are allowable for the same reasons as applicant considers the amended claims to be allowable.

Turning now to the claims rejection under 35 USC Paragraph 103, the Examiner cited the combination of references of Rinderle, in view of Reifenhauser US Patent No. 4,488,861 as rendering these claims obvious. Claims 15 and 16 were rewritten as new claims 32 and 33. These claims have also been amended to distinguish further over Rinderle, as well as any possible combination of Rinderle and Reifenhauser. In any event, applicant does not consider the combination to be a valid combination.

Firstly, it is respectfully submitted that there is no motivation shown in either Reifenhauser or in Rinderle to combine these references. To provide for a combination of references, there must be some motivation in either one of the references to show where such combination is considered possible from either one. Furthermore, since Rinderle is a later issued patent, if there were some motivation in some form of combination or inclusion of the teachings, it would seem that Rinderle would have

included it, and this should be evident from a consideration of Rinderle that there has not been any.

As best as applicants can ascertain, Reifenhauser is not concerned with a mould, but an arrangement in which a nozzle area assists in the flow of a plastic material. Therefore, the current combination is not understood and the specific applications also not understood. Moreover, the Reifenhauser application is directed to a different subject matter. It is the Examiner who suggests such teaching, not Reifenhauser or Rinderle.

With respect to the other references of record, these have been considered, and they are not considered pertinent to the claims of the present application.

With respect to claims 32 and 33, in order to draw a further distinction between the references of record and, in particular, the combination of Rinderle and Reifenhauser, applicant wishes to point out that claim 33 has been amended to set forth that each of the at least one closed chamber is integrated with the mould. Further, claim 32 has been amended to indicate that each of the at least one closed chamber with the liquid therein, and the air is extracted above the liquid. This specific teaching is not seen anywhere in the heretofore mentioned references or the other references of record.

With respect to the present invention, the mould, the method and the system utilize the ability of water to boil at low temperatures when maintained at very low pressure. (At 0.5 psi, the boiling point is 25°C). This is a specific example, but other liquids with their associated boiling point at a low temperature can also be used.

Water absorbs heat at an enormous rate under these conditions, and, since it is

only necessary for water to contact the target surface for this effect to occur, forced flow circuits are not required within a die plate.

In fact, all that a die plate requires is a single gallery, shaped to suit the shape of the part, machined directly into its back surface.

Figures (1) and (2), attached as an enclosure, show an exploded view of the core side of a basic mould assembly which has been designed to demonstrate the system.

1. Efficiency

The effectiveness of conventional mould cooling methods is limited mainly by three factors:

a) It is often difficult to access all areas of the mould with cooling circuits. This leads to uneven surface temperatures and, since the moulding cycle rate is usually governed by the temperature of the hottest areas, efficiency suffers. Uneven mould surface temperatures are also a major cause of quality problems. Even with the best possible layout, significant gradients still occur between the channels of those circuits.

b) When multiple circuits are used, equalization of the surface temperatures of the mould is even harder to achieve (even if all areas of the mould are serviced) because of the difficulty of balancing the rates at which each circuit extracts heat.

c) The transfer of heat to the coolant water is affected by the low thermal conductivity of water. Also, it is necessary to maintain sufficient coolant velocity through the circuits to create significant turbulence, otherwise efficiency is severely reduced. Conflict results between the need to maximize the surface area of the die in contact with the coolant and the need to minimize the section size of the circuits for the sake of coolant velocity. Compromise becomes necessary. Efficiency is also lost because heat is exchanged between the incoming coolant and the outgoing coolant.

In effect, the mould is a heat exchanger. Because of the above limitations, it is

generally not a very efficient heat exchanger.

These problems are virtually eliminated by the applicant's mould, method, and mould system.

The system of the present invention, as well as the method and mould achieves the desired objectives because:

a) Most areas of a mould can be accessed by the coolant, regardless of mould complexity, (the only exception is a core which is too small to be hollowed out), so that evenness of moulding surface temperatures is readily achieved. Also, it is usually easy to build in a deliberate bias for some areas (e.g. opposite the gating point or around a hot nozzle.) Quality problems associated with differential cooling rates are automatically minimized and the moulding cycle time becomes a function of the general mould temperature.

b) Multiple circuits are not normally needed, but are easy to balance if they are required.

c) Heat is transferred directly to the internal coolant water at the interface. The thermal conductivity of water is not a factor. Heat arriving at the interface is immediately converted to latent heat of vaporization - (the water boils). This is an isothermal process, i.e. heat is taken up by the water without increasing its temperature. The capacity of the water to take up heat in this manner is over 500 calories per cc. With conventional methods the water takes up heat at the rate of 1 calorie per cc for each degree of increase in its temperature.

   The only limitations to the evenness of cooling come from the need to structure the low pressure chamber so that mould strength does not become inadequate and from the difficulty of getting coolant into long cores which have a diameter of less than 2.5 mm. The effect of structural compromises need not be significant. There is no 'magic' solution to the problem of tiny cores but this system comes very close. The use of copper alloy inserts may still be beneficial in some cases.

   Having efficiently transferred the heat from the 'working' area to the internal coolant water, it is then necessary to remove it from that coolant water. This is achieved using a small, efficient, in-built heat exchanger, which extracts the latent heat of vaporization from the water vapor, i.e. it condenses the water vapor back to liquid. The condensate then flows back to the working area.

Since the system provides efficient, even cooling of the mould, the speed of

production is limited only by the capability of the moulding machine, the thickness and characteristics of the material being processed and the need to maintain mould strength.

2. Ease of Maintenance

The only area which may be susceptible to corrosion and sludge accumulation is the core of the heat exchanger and the inside surface of the heat exchanger body. This core can be removed for cleaning and drying by simply unscrewing it from the mould. The inside surface of the heat exchanger body is also then accessible for servicing.

There is no need to disturb the low-pressure chamber of the system and, since air is deliberately excluded from this area, it cannot suffer from corrosion.

The heat exchanger is designed to provide a high level of turbulence in the flow of the coolant. The scouring action of that turbulence discourages sludge from accumulating.

The core and body can be made from corrosion resistant materials, which are good conductors of heat. Copper and brass are examples of suitable materials. Brass is the preferred material.

If the above surfaces are cleaned and dried at the end of each production run, then corrosion in this area will be negligible.

In the unlikely event that corrosion in the heat exchanger does reach unacceptable levels, it is cheap and easy to replace.

3. Charging of Low Pressure Zone

In order to achieve the required operating pressures, it is necessary to remove as much air as practicable from the low-pressure chamber. This can be achieved by

raising the temperature of the internal coolant to a level higher than its normal pressure boiling point. Under this condition, the coolant will boil and the vapor produced can be used to flush any unwanted residual gases from the system. When using low boiling point fluids this presents no problem.

When water is used as the coolant, the required temperature is 100°C. Heating a mould to such temperatures is usually not practical so methods are needed to allow for the system to be charged using water at normal temperatures.

Using a conventional powered vacuum pump, the system can be simply filled with the appropriate amount of water and then the vacuum pump can be applied at the evacuation port and operated until the pressure level stabilizes at a level corresponding to the vapor pressure of water at the ambient temperature. This process need not take more than a few minutes.

Due care must be taken with the sealing of all joints to ensure that air does not leak back into the chamber. Periodical recharging may be required. Experience to date is limited, but indications are that a properly sealed unit retains its pressure level for several months at least. (The system is no more demanding in this respect than conventional systems - leaky cooling systems are always bad news.)

4. Temperature Control

In order to minimize moulding cycle times, it is desirable to keep the temperature of the mould at the lowest possible level. This system provides an efficient means of achieving that objective.

It is often necessary however to operate a mould at elevated temperatures in order to achieve product quality objectives. The conventional method of achieving this

is to control the temperature of the water passing through the mould's water circuits.

An alternative, but inferior method is to restrict the flow of the water through the mould. Slower flow rates result in higher average mould temperatures, but creates undesirable temperature gradients along the water flow paths. The level of control achieved is also very poor.

With the system as disclosed and claimed, the mould temperature is automatically 'evened out'. Evaporation always occurs preferentially at the hottest point, thereby reducing its temperature to that of its surrounds. (The process is naturally 'isothermal').

There is no need to control the temperature of the external coolant apart from ensuring that it is cold enough.

The mould temperature can be controlled very evenly and effectively by controlling the flow of the external coolant through the heat exchanger. A simple thermostat can be used to monitor the temperature of the internal coolant and, by operating a solenoid valve, interrupt the flow of external coolant whenever the temperature falls, say, 1°C below a preset value and restores it whenever it rises 1°C above that preset value. The temperature of the external coolant at the outlet side may vary considerably as a result, but the internal coolant temperature (and therefore the temperature of the moulding surfaces) is under tight control.

It is sometimes beneficial to pre-heat a mould so that production can start with the mould already at its operating temperature. This is readily achieved by the inclusion of an 'optional extra'. The system provides for the fitment of a cartridge-heating element near the mould's lower edge. A circulation channel adjacent to the element

allows the internal coolant to transfer the heat from the element to the working area of the mould. (When the water boils, it percolates through the low-pressure zone, the vapor condenses and water flows back.) The thermostat is programmed to activate the heating element if the mould temperature is 5°C below the preset value.

Using water as the latent heat transfer medium, the system is very effective for internal coolant temperatures above 20°C. As the operating temperature falls, the process loses efficiency. The density of the water vapor falls rapidly as the temperature falls below 20°C and its ability to transfer heat becomes affected by the sheer volume of vapor that needs to be moved. To operate at temperatures below this level, it can be more practical to use a low boiling point fluid as the internal coolant (e.g. the refrigerant, R134A). The only advantage lost is the environmental 'friendliness' of water, but the end result is no less friendly than the sealed unit in a refrigerator.

Another advantage realized by the system, method and mould of this invention is a significant reduction in problems caused by condensation when using refrigerated water in a humid environment. Since the external coolant is circulated **only** through the inside of the heat exchanger, it is isolated from the rest of the mould. The internal coolant only affects the operating surfaces of the mould, which normally don't run cold enough for condensation to occur even if an external coolant temperature of 5°C is used.

Cooling energy is not wasted on surfaces that don't need to be cooled.

5. Experimental Results

A prototype unit has been made and tested. This unit was designed to represent the core half of a typical mould with a face area 250mm square and a protruding core, 70mm Dia. x 55mm long. The core was hollowed out to create the low-pressure chamber leaving a wall thickness of 12mm.

The effectiveness of the cooling action was tested as follows:

1) Coolant water was supplied to the heat exchanger at a temperature of 27°C. (The ambient temperature at the time of the test)

2) Two gas blow torches were directed at the surface of the core.

3) The temperature of the coolant, of the core and of the water in the low-pressure chamber were monitored using pyrometers with digital displays.

4) The flow rate of the coolant was monitored using a watch and a standard one-liter container.

5) The flow rate of coolant was adjusted until a flow rate of 4 liters per minute was achieved and the output of the blow torches was adjusted until a temperature rise of 2.7°C in the external coolant was achieved. This corresponds to a heat extraction rate of 754 watts. The amount of water, which needs to boil in order to achieve this result, is only 20 cc per minute. With one unit on each side of a mould, this equates approximately to a production rate of 17 Kg of polypropylene product per hour (e.g. a 20 gm shot every 4.2 seconds.)

6) The temperature of the core under the above conditions was found to be 48°C. which is 21°C above the coolant temperature. This is a very satisfactory result.

7) The temperature of the water in the low-pressure chamber was found to be 35°C. which is 13°C less than the core surface temperature.

Direct calculation of the expected temperatures, based on the geometry of the core and the test conditions, were also made. The calculated temperature differential through the walls of the core is 12°C. This corresponds very well with the experimental results. The remainder of the temperature differential (8°C) is a function of the capacity

of the heat exchanger.

A test mould has been manufactured and tested with the objective of proving the effectiveness of the system. Except for the cooling system, this mould was identical to an existing mould, so a direct comparison could be made. The mould according to the teachings of this invention returned a 50% reduction in cooling time, resulting in a **total cycle** improvement of 20%.

From these results it can be seen that the ability of the system to control the temperature of the operating surface of a mould is limited only by the capacity of the heat exchanger and the wall thickness of the mould.

6 Thermodynamic Calculations

The thermodynamics of a mould, which uses this system and method, are very simple. As a result, comparatively simple mathematical modeling can be used to determine heat exchanger specifications and to make meaningful predictions of moulding cycle times.

The two primary factors, which control the time required for a moulding to 'cure', are the wall thickness of the part and the ability of the mould to dissipate heat.

The 'curing ' time for a part of wall thickness W cm can be calculated using the following formula:

$$t_c = 1.017 \times (a \times W / Pi)^2 \times Ln\{4 \times (T_m - T_d) / (T_c - T_d) / Pi\} \qquad (1)$$

Where

$a = (p \times c / k_p)^{1/2}$

T_m = temperature of the molten plastic material.

T_d = working temperature of the moulding surface.

T_c = temperature required at center of the part's wall for safe ejection from mould.

p = density of the plastic material.

c = specific heat of the plastic material.

k_p = thermal conductivity of the plastic material.

Note: equation (1) is an approximation derived from an equation, which contains the sum of a highly convergent infinite series. For values of T_c which are less than 60% of T_m, it is correct to 3 significant figures. This condition is met for all practical values of T_c. Also, the assumption is made that full contact is maintained between the part and the mould.

Consider a part moulded from polypropylene at a melt temperature of 230°C. For polypropylene,

p = 0.89 gm/cm^3
c = 2.1 Joules/gm/°C
k_p = 0.001138 Watts/cm/°C

Using 120°C as the value for T_c, the curing time can then be calculated for parts of various wall thickness using a number of mould surface temperatures which can be expected for a given combination of wall thickness and mould temperature.)

It is then possible to calculate the rate at which the plastic part gives up heat to the mould.

The amount of heat lost to the mould by a $1cm^2$ section of the part is given by:

$H = (T_m-(T_c+T_d) / 2) \times W \times p \times c$ Joules (2)

(For simplicity it has been assumed that the temperature profile through the wall of the part is linear. The error caused by this approximation results in a slight overestimation

of the value of H).

Knowing the curing time and the moulding machine's operating speeds, the total cycle time can be estimated.

Let's consider an example part which is 1 mm thick, moulded in a die, which has its average surface temperature, maintained at 45°C.

From equation (1) the cure time for the part is 1.9 sec. The time required to open the mould, eject the part and close it again would account for say, an additional 2 seconds and, depending on the size of the part, a further time of say, 0,6 seconds would be required for filling the cavity. Assuming that the machine's screw recovery time is not a limiting factor, this gives an estimated total cycle time, C, of 4.5 seconds.

From equation (2) the value of H is 27.6 Joules/cm^2. This heat is transferred to the mould in about 1,9sec. The mould, however, has 4.5 seconds in which to dissipate that heat.

The rate of dissipation of heat by the mould, Q, is then given by

$Q = H/C = 27.6 / 4.5 = 6.13$ Watts/cm^2.

Since that heat is directed in two directions (to the 2 halves of the mould) we can then deduce that each half of the mould needs to dissipate heat at the rate of 3.07 Watts for each square cm of plastic in contact with it. (If the part has significant ribbing on one side, then the sharing proportions would need to be adjusted accordingly). Let q be this share of the total.

If the effective distance from the mould's working surface to its coolant is D then the temperature of the coolant will need to be maintained at a level given by the following equation:

$T_w = T_d - D \times q / k_m$ (3)

Where k_m = Thermal conductivity of the mould material.

For a mould manufactured from P20 steel, k_m = 0.379 Watts/cm/°C

If D has a value of 1.5 cm then from equation (3) the value of T_w is 32.8°C.

In order to specify the performance requirements of the heat exchanger, it is necessary to know the temperature of the cooling water supply.

It is also necessary to know the rate of heat dissipation required for the full part. This is obtained simply by multiplying q by the surface area of the part in contact with the half of the mould for which the calculation is being made. Suppose the example part is flat and 20 cm square. This gives it a surface area of 400 cm^2 and the dissipation rate required is 1228 Watts.

All the tool designer needs to do then is to choose a standard heat exchanger made in accordance with the teachings of this invention which is rated to provide a dissipation rate of at least 1228 watts with a temperature rise of not more than the difference between 32.8°C and the temperature of the water supply.

Having concluded this analysis, one can then be confident that the cooling system is not the cause or reason if the estimated moulding cycle time of 4.5 seconds is not achieved.

The accuracy of this analysis method will be affected by complexities in the shape of the part being analyzed. As part complexity increases the value needed for T_w will tend to be overestimated. An experienced designer should be able to make appropriate allowances for this when setting the heat exchanger performance specifications.

The value chosen for T_c will depend on the thickness of the part being moulded. For thicknesses up to 2.5 mm, a value, which is about 20°C less than the vicat softening temperature provides a good safety margin for making calculations. As thickness increases, this temperature can be increased.

The method, mould and system of the present invention, is an excellent general solution to the problem of mould temperature control. It enables a tool designer to create mould designs, which are engineered to a level, which he previously could not contemplate. The moulder can have much greater confidence in his or her accuracy when estimating the cost of new products and the moulder can expect to achieve significant improvements in the quality and efficiency of the production processes.

As will be evident from the foregoing, the invention is specifically applicable to moulds used for plastic injection and the invention solves a number of very difficult problems that have hitherto plagued this particular area.

With respect to the cited case, and the Examiner rejection of the claims with respect to material extended to be worked on, it should be noted that applicant's invention is primarily intended for plastic materials, particularly since there are all types of materials which can be moulded. A further point is that since the Examiner has cited plastic injection molding patents, no distinction from the prior art is being made on this basis except to demonstrate that in this very narrow art, applicant's invention is a clear improvement over other disclosures in this narrow field of technology.

The technique particularly allows for effective heat transmission through the die or mould so that the total overall temperature of the die or mould is kept relatively uniform and heat can be gotten rid of by having external cooling water somewhere in

the top of the die or mould where it can act in a very efficient way by acting to condense the water or liquid vapor.

However, apart from a relatively small area of the die or mould, the traditional techniques of using cooling water that continuously flows through pretty much all of the die or mould is no longer needed.

As the Examiner will now readily appreciate this then provides firstly for significantly reduced cycle times through an injection molding process and further, because external water or liquid is not being introduced other than through a very small portion of the mould, the life of the die or mould can be expected to be very much longer.

There is quite simply nothing that the inventor knows of that solves these particular problems in this way. Also, a pointed out heretofore, Rinderle does understand the problem that the applicant wants to solve and Rinderle has an answer, which is different from that of the applicant of this application, and as pointed out above, Rinderle does not achieve what the applicant has achieved.

If there are any points outstanding, the Examiner has respectfully asked to call applicant's Attorney in order to do what is necessary to place the application into condition for allowance.

Early and favorable reconsideration together with the allowance of this application is respectfully solicited.

Respectfully submitted,

LACKENBACH SIEGEL

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JHN:ar
Enclosure: Acknowledgement Card
Figure (1) and (2) (For Argument)

Certificate of Deposit by Mail

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Attorney

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October 1, 2002
Date

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